SPY-1D(V) Models and Simulations Support Operational Testing in a Remote New Jersey Cornfield

PEO, Developer, Operational Tester Combination Works Smarter, Placing Best Technology in Warfighters' Hands

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Accredited models and simulations make land-based testing of the SPY-1 radar family more credible than ever before. This article is about one such operational radar test, conducted in a remote New Jersey cornfield.

AEGIS COMBAT SYSTEM ENGINEERING DEVELOPMENT SITE (CSEDS), HOME OF THE "CORNFIELD CRUISER"

Photo courtesy Unisys Corporation

Also in this article, we explain the verification, validation, and accreditation of the SPY-1D(V) program models and simulations, and how this process not only ensures the proper use of high-fidelity, thoroughly understood models and simulations, but also enhances the realism and credibility of operational testing. Further, we describe development and application of this accreditation process in support of the recent SPY-1D(V) radar test; focus on the managerial versus the technical aspect of this process; and present potentially useful ideas to organizations involved with modeling and simulation in the operational test and evaluation arena.

Navy's SPY-1D(V) Strategy Decision

In 1994, the Navy faced an important acquisition strategy decision – important because the AEGIS SPY radar system is completely integrated into the AEGIS ship, and it takes five years to build a ship. Two options emerged for consideration:

Option 1. Produce and install a single SPY-1D(V) radar in a new construction DDG 51-class ship.

Option 2. Use the land-based test site to test operationally the engineering development model of the SPY-1D(V) radar.

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Option 1 would cause the interruption of SPY-1D radar production and create a unique operational ship for the sole purpose of at-sea testing to support a low-rate initial production acquisition decision. This option would have the advantage of testing in the operational environment, but the disadvantage of delaying fleet introduction of SPY-1D(V) radars for up to five years and incurring additional costs for creating a unique asset and conducting two SPY-1D(V) production starts versus one.

Option 2 called for land-based testing to support a low-rate initial production acquisition decision without interfering with current radar/ship production. This option had the advantage of making the acquisition decision in 1996 vice 2003-plus, but the disadvantage of testing in a land-based operating environment.

Key to the Navy's SPY-1D(V) strategy decision was a determination that land-based testing was adequate to support a low-rate initial production decision. Toward that end, the Navy planned to conduct this land-based testing at its Combat Systems Engineering Development Site (CSEDS) in Moorestown, New Jersey. Due to its land-locked location, CSEDS' characteristics are vastly different from any shipboard environment, and those differences remained to be assessed.

The CSEDS facility is 50 miles from the Atlantic Ocean in a location that prohibits low-flying aircraft and severely restricts chaff and electronic jamming activities. Any test scenarios involving fixed wing aircraft, helicopters, chaff, and jamming must be conducted in areas that do not interfere with commercial airways, nearby subdivisions, or local farm animals. Site characteristics bear little resemblance to the at-sea operating environment of dynamic sea clutter, multipath low elevation propagation, and pitching and yawing conditions a radar will operate in when installed in a Navy ship. The testing methods for SPY-1D(V)'s new capabilities were all adversely impacted by CSEDS' site limitations.

SPY-1D(V) RADAR. THE AEGIS SPY RADAR SYSTEM IS COMPLETELY INTEGRATED INTO THE AEGIS DESTROYER FLEET.
U.S. Navy photo

To help make the test adequacy determination, the Assistant Secretary of the Navy (Research, Development, and Acquisition) (ASN[RDA]) commissioned an independent advisory committee to investigate the SPY-1D(V)'s capabilities and CSEDS characteristics. After assessing risk mitigation, technical risks, and test adequacy, this independent committee concluded that, with the use of models and simulations, the radar could be tested well enough to support the low-rate initial production decision. Based in part on this conclusion, ASN(RDA) chose Option 2 and signed an Acquisition Decision Memorandum authorizing land-based operational testing at CSEDS.

ASN(RDA)'s decision complemented the growing trend within the Department of Defense (DoD) to find alternatives for the ever-increasing costs and rapidly shrinking resources associated with test and evaluation requirements, particularly requirements associated with field tests. One alternative is the use of models and simulations. DoD has moved toward models and simulations as a way to cut expenses in developmental and operational testing. Real-world assets such as very small targets, aircraft services, and missile firings are becoming increasingly scarce and expensive. Some acquisition programs have been using models and simulations for years and have established methodologies for conducting verification and validation.

The Verification, Validation, and Accreditation Process

To the Navy's independent test agency – Commander, Operational Test and Evaluation Force (COMOPTEVFOR) – the idea of using models and simulations instead of actual field operations to validate at-sea systems' performance was a departure from traditionally accepted testing methodology. To the COMOPTEVFOR staff, who experienced and well understood at-sea realities, the modeling of the SPY-1D(V)'s new capabilities for operational applications had little credibility because CSEDS is land-locked.

COMOPTEVFOR supported the move toward models and simulations by developing a command concept and procedure that outlined how models and simulations fits into operational testing. Involving a process called verification, validation, and accreditation, this concept calls for a program executive office to verify and validate all the models and simulations it requires to perform necessary developmental and engineering tests. Ideally, the verification and validation process should satisfy the program executive office that the selected models and simulations function as expected. When the program executive office is satisfied, it formally accepts the models and simulations for use in developmental testing. This formal acceptance is called certification, and is the measure of the program office's confidence in its model. After certification, the program executive office directs the model's use in the developmental test strategy. If the models and simulations will be used in an operational test, COMOPTEVFOR must accredit the models and simulations for a specific purpose within that test. Accreditation is the COMOPTEVFOR formal acceptance of the validated models and simulations. COMOPTEVFOR always considers certification a prerequisite to accreditation.

Step 1. The Simulation Management Plan (SMP). Neither the Program Executive Office Surface Combatants-AEGIS Program (PEO SC-AP) nor COMOPTEVFOR possessed the experience or the infrastructure to support any of the new models and simulations initiatives, including verification, validation, and accreditation. Some of the basic concepts were there such as certification and accreditation, but few of the real-world mechanics. Those mechanics had to be created.

As the first step, we found a working models and simulations organization. As a result of using models and simulations for years, the Tomahawk Cruise Missile Program possessed practical experience, which it willingly shared. The PEO SC-AP and COMOPTEVFOR staff members, however, faced the daunting task of mastering the Tomahawk methodology; the COMOPTEVFOR verification, validation, and accreditation instruction; the program executive office and COMOPTEVFOR goals; and the time and financial constraints on the entire process. Once they digested all these elements, the program executive office and COMOPTEVFOR staffs jointly authored a verification, validation, and accreditation plan, called the SPY-1D(V) Radar System DT/OT Simulation Management Plan (SMP).

First SMP Component – The Goals

The establishment of goals by each participating office is the first component of the SMP. Once established, each office must clearly understand the goals of all other offices and jointly design a framework that will mutually support the achievement of all goals.

Accreditation of those models that supported its mission – the operational test – was COMOPTEVFOR's primary goal. In this case, accreditation required seven models/simulations/simulators/stimulations. Only after a thorough review of the verification and validation process to determine the fidelity of each model in supporting operational testing, was accreditation awarded. Prior to accreditation, we prepared and reviewed the following required documents for each model (discussed at length in subsequent paragraphs):

- Simulation Validation Plan
- Simulation Validation Report
- Simulation Version Description Document
- Program Executive Office Certification

No requirement exists that any model must exactly replicate the real world; in other words, no model is expected to be a "perfect" empirical representation.

Alternately, one of the program executive office's major goals was the accreditation of its models and simulations. Accreditation meant that the SPY-1D(V) models and simulations were credible enough to conduct the test strategy outlined in ASN(RDA)'s Acquisition Decision Memorandum. Accreditation also meant that an outside activity reinforced the program executive office's reputation for enforcing standards. Since certification was a prerequisite to accreditation, the SMP outlined the program executive office's certification requirements as well.

Second SMP Component – Verification and Validation Method

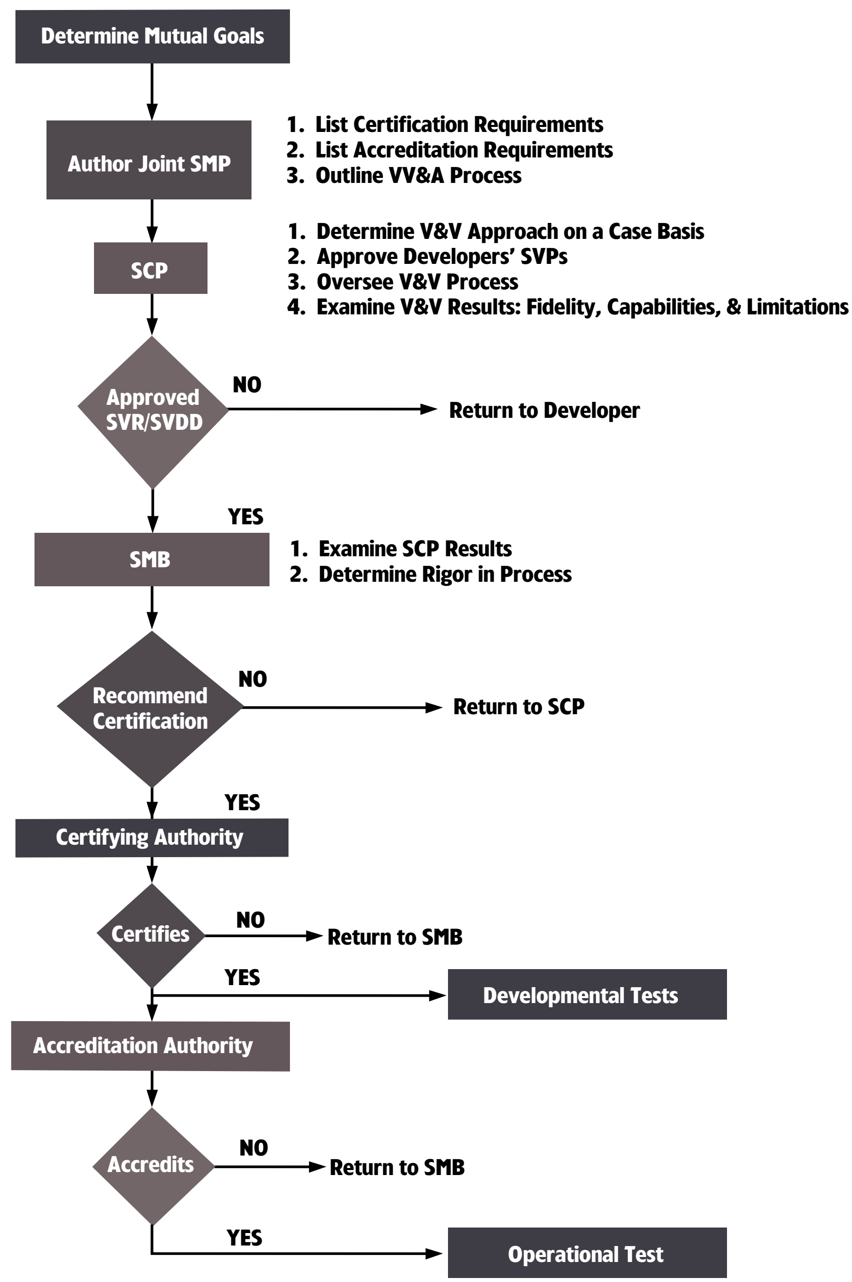
The other major component in the SMP is the actual verification and validation execution framework. The preferred, overarching theoretical concept of verification and validation calls for a disinterested third party to accomplish validation. This type of validation is known as independent verification and validation. For the SPY-1D(V), neither the time nor the money existed to contract such a party to independent verification and validation — all seven required models and simulations. Instead, the SMP authorized an internal verification and validation method, the use of which represented a need to mitigate any credibility risk to the program. This meant that the models and simulations developers would validate their own models with program executive office and COMOPTEVFOR oversight instead of independent verification and validation.

Again, in the interest of time and money, the SMP did not require new data collection. In other words, for certain models the developers were not tasked to acquire new empirical data to support verification and validation. New collection and analysis of atmospheric propagation, sea clutter, or live missile telemetry data was impractical. This information already existed in several places and could be used at significant time and cost savings.

Third SMP Component – Credibility
Next, PEO SC-AP and COMOPTEVFOR agreed that their staffs must maintain ruthless self-discipline to reduce risk and ensure credibility since independent verification and validation would not be used. All verification, validation, and accreditation procedures, results, and discussions would be open to outside agencies' inspection. This openness philosophy was the cornerstone of the entire effort's success.

Fourth SMP Component – The Framework
Finally, the SMP provided the organizational structure to achieve the goals and execute the verification and validation method. This structure consisted of the Simulation Management Board (SMB) and the Simulation Control Panel (SCP). The SMP required the use of the SMB and the SCP and provided an executive summary of their functions. The SMP also described each one's membership and its role in accomplishing certification and accreditation.

SPY-1D(V) Accreditation Process



SMP	Simulation Management Plan
VV&A	Verification, Validation, and Accreditation
SCP	Simulation Control Panel
SVR	Simulation Validation Report
SVDD	Simulation Version Description Document
SMB	Simulation Management Board

Step 2. The Simulation Control Panel (SCP). The SCP provided the working technical oversight of the verification and validation process. Its composition included mainly technical personnel, who well understood their respective models and simulations, as well as AEGIS combat system technical representatives. Part of the SCP's function was to promote a technical exchange.

The SCP – Its Membership
The SCP's chairperson was the SPY-1D(V) program manager's assistant. The co-chairperson was the COMOPTEVFOR operational test director for the SPY radar program. These two individuals directed the oversight process. It is important to note that both co-chairpersons had to be in agreement for any item to pass the SCP. Other members included technical representatives from the three companies who developed the models and simulations, namely Lockheed Martin (Government Electronic Systems) Corporation, Technology Service Corporation, and Systems Engineering Group. Additionally, the Naval Surface Warfare Center and AEGIS Technical Representative provided technical support to the program executive office chairperson, and the Center for Naval Analyses supported the COMOPTEVFOR co-chairperson.

The SCP – Its Function
As previously mentioned, the SCP's charter was to perform the working-level oversight of the verification and validation process. Toward that end, the membership devoted a good deal of time and effort to understanding and defining the seven models and simulations. When the SCP leadership believed they achieved a sufficient understanding of each model and simulation, they asked the developer to propose a verification and validation plan based on its assets and the data available. When the developer eventually submitted a proposal, the membership then discussed it at length and selected the actual process the developer would use to validate the models and simulations.

"When the SCP leadership believed they achieved a sufficient understanding of each model and simulation, they asked the developer to propose a verification and validation plan based on its assets and the data available."

Most of the early meetings centered around selecting the proper verification and validation method. Sometimes these discussions were rather frank and resulted in some strong disagreements, but fortunately the SMP did not require unanimity. Once the co-chairpersons accepted the validation proposal, the developers proceeded to write the Simulation Validation Plan. The SCP met frequently to monitor validation progress. Sometimes, of necessity, the SCP changed verification and validation procedures because the developer found a better way or discovered the current method wasn't working as planned. The SCP membership carefully reviewed validation progress and early results to ensure they met the objectives initially outlined in the SMP. As verification and validation progressed, the developers began to write the Simulation Validation Report and the Simulation Version Description Document.

The Simulation Validation Plan
Groundwork. The SMP required a separate Simulation Validation Plan for each model and simulation. As previously noted, early SCP meetings centered around determining which verification and validation method to employ for each model and simulation. During those determinations and in order to author the Simulation Validation Plan, several questions remained to be answered, or at least addressed:

Is the model and simulation a model? (A model is defined as a physical, mathematical, or otherwise logical representation of a system entity, phenomenon, or process.)

Is the model and simulation a simulation? (A simulation is defined as a method for implementing a model over time, or where real-world and conceptual systems are reproduced by a model.)

For what purpose will the model and simulation be used?

What are the capabilities and limitations of each model and simulation?

What value will the model and simulation add to the operational test?

How will use of each model and simulation impact the operational tester's ability to formulate conclusions?

How does the model interoperate with the other six models?

What options exist within the time/money/data constraints to verify and validate each model?

In practice, the SCP answered some of these questions only after they approved the Simulation Validation Plan, and the interoperability issue was never completely addressed. The SCP intended the verification and validation process to be flexible. When the panel found a better way, they altered the process and sometimes changed an answer too. Once the SCP assembled sufficient information, it addressed requirements for the Simulation Validation Plan.

Two Simulation Validation Plan Requirements. The first Simulation Validation Plan requirement was the selection of the right method based on the SCP's understanding of the models and simulations . As a result, the SMP mandated that the verification and validation process use at least one of three possible methods:

- Model-to-Real-World Comparison

- Model-to-Model Comparison

- Code Analysis

For SPY-1D(V), a model-to-real-world example was the simulation that represented small radar cross-section targets. Because no real-world targets existed, the developer used the model-to-real-world simulation, attaching a physical sphere to a balloon and launching it into the air. This sphere had a known cross-section that fluctuated in the real environment. As it floated away, the SPY-1D(V) radar tracked the sphere. It also tracked a target simulation constructed with the same cross-section. Unlike the sphere, however, the target simulation possessed no cross-section fluctuating capability. We then compared the sphere's cross-section, as observed by the radar, to the simulation's cross-section as observed by the radar. Results determined the corrective action necessary to improve the simulation.

A model-to-model example was the sea clutter simulation. We used this simulation because CSEDS is a long way from the ocean. The simulation was actually a composite of two models and simulations — a mathematical model, representing the sea clutter phenomenon; and a hardware generator, which implemented the model into the system such that the radar could observe the sea clutter. Validation of the generator's implementation ability compared the mathematical model with the generator's simulation. The results initiated a plan of action.

The second requirement stipulated that the known capabilities and limitations of the models and simulations be stated. Every Simulation Validation Plan included a list of the known capabilities and limitations of its model to preclude future misunderstandings. The unforeseen benefit of this requirement was the discovery that the "known" capabilities and limitations listed in the Simulation Validation Plan were not necessarily the same ones revealed later during verification and validation.

As verification and validation progressed, the SCP began to author the next two required documents, the Simulation Validation Report and the Simulation Version Description Document.

The Simulation Validation Report

The Simulation Validation Report was the written report of results achieved during verification and validation. It contained an executive summary and a technical analysis section. Included in the Simulation Validation Report were validation details such as —

- a description of the actual validation procedure;

- a discussion of why that procedure differed from the one outlined in the Simulation Validation Plan; and

- a list of capabilities and limitations confirmed by the verification and validation. Where the Simulation Validation Plan and Simulation Validation Report lists differed, the developer added an explanatory note.

The Simulation Version Description Document

The Simulation Version Description Document briefly described the computer program configuration management that supported the models and simulations. The developer met this SMP requirement chiefly through a related, non-accreditation event called a COMOPTEVFOR Software Quicklook. A Software Quicklook provided COMOPTEVFOR with a basic understanding of a developer's software management program.

The program executive office had previously encouraged the conduct of a Software Quicklook to promote COMOPTEVFOR's understanding of configuration management issues. A thorough review of the Quicklook confirmed that the prime developer followed accepted software configuration management procedures, further increasing COMOPTEVFOR's confidence in the models and simulations. Since the Quicklook is not a verification, validation, and accreditation requirement, it did not eliminate the accreditation requirement for a Simulation Version Description Document. However, using Quicklook data, the SCP could streamline the document.

Now verification and validation was complete. The SCP had written a Simulation Validation Plan, and the developers had executed it. The approved Simulation Validation Report contained an executive summary and the technical results. The Simulation Version Description Document was complete.

The co-chairpersons agreed to move the verification, validation, and accreditation process forward. The next step was to convene the Simulation Management Board.

Step 3. The Simulation Management Board (SMB). The SMB was a fourmember board, chaired by the SPY-1D(V) program manager. Its purpose was to recommend certification to the program executive office certifying officer. Prior to recommending certification, it evaluated the Simulation Validation Reports provided by the SCP. The SMB voting members were the chairperson, the PEO SC-AP models and simulation division head, and an AEGIS Technical Representative senior staff member. The COMOPTEVFOR Assistant Chief of Staff for Surface Warfare acted as the single, nonvoting advisory member.

The SMB acted to satisfy its membership that the verification and validation had been rigorously executed. In that regard, the board consulted the COMOPTEVFOR advisory member for the accreditation authority's perspective on the verification and validation results. When the vote was unanimous, the board forwarded a certification recommendation to the proper authority at the program executive office. When the vote was not unanimous, the board returned the product to the SCP for additional work.

The SMB/SCP membership intended their proceedings to be an open process. Interested parties from the Director, Operational Test and Evaluation and the Institute for Defense Analyses had a standing invitation to attend either board/panel. The membership extended this standing invitation for two purposes:

- Without specific DoD guidance, the SPY-1D(V) joint verification, validation, and accreditation effort was somewhat "experimental." Agencies closer to DoD might be able to provide additional perspectives on the future evolution of models and simulations policy.

- The demonstration of the rigorous, disciplined process should be witnessed and not merely advertised.

Step 4. Certification and Accreditation The SMB chairman briefed the certifying authority on the results and recommendations of the SMB. This authority certified the recommended models and simulations when convinced that the SMB had applied the requisite tough examination required by the SMP tenet of self-discipline. After the program executive office completed its internal administration, the certifying official then sent an official letter of certification to the accreditation authority.

Upon receipt, the OPTEVFOR operational test director briefed the accrediting officer on the certification letter. Included in the brief was a synopsis of the technical details from each Simulation Validation Report, including capabilities and limitations; the intended use of the models and simulations in the operational test; and an assessment of whether the ability to draw conclusions was affected. The brief also discussed how well the developer met COMOPTEVFOR requirements, and then provided recommendations. COMOPTEVFOR accredited the models and simulations when convinced that the program executive office/COMOPTEVFOR/developer working team had satisfactorily executed its charter.

The operational test director was now able to complete the test plan, obtain its approval from the appropriate authority, and conduct the operational test. Afterwards, the data analysis, final report, and test results briefings relied heavily upon the verification, validation, and accreditation effort.

Future Challenges

The successful achievement of certification and accreditation for the operational test did not mean the end of the SPY-1D(V) validation, verification, and accreditation process. As expected, the subsequent briefings provided to PEO SC-AP, COMOPTEVFOR, and the Director, Operational Test and Evaluation resulted in feedback. Thus, some new challenges arose:

- Expand existing databases by collecting new empirical real-world data.

- Refine models and simulations fidelity, such as the sea clutter mathematical model, to more closely approximate real sea clutter.

- Increase the capabilities of essential models and simulations, such as incorporating a fluctuating radar cross-section behavior in the simulated targets.

- Overcome certain limitations, such as the sea clutter generator's inability to implement fully the sea clutter model.

- Improve the verification, validation, and accreditation process.

- Investigate new models and simulations that will add value to future developmental and operational tests.

Lessons Learned

In reality, the functioning of the verification, validation, and accreditation process was not nearly as clean or linear as outlined in this article. In some cases, the developer wrote the Simulation Validation Plan and the Simulation Validation Report concurrently; for example, if a validation procedure proved impractical halfway through, and another method had to be implemented. In other cases, a model's verification and validation yielded an unexpected result. Once we found that a model intended for use displayed an undesired, less-realistic effect when compared to other industry models. Ultimately, we discarded this model and selected a substitute. For reasons like these, the SCP was educational for all its members.

We continued to assimilate lessons learned throughout the course of this verification, validation, and accreditation process. A brief description and solution for three of these lessons follow:

Lesson 1
We originally constructed the SCP as a voting body, similar in makeup to the SMB. However, at this level a simple majority vote consisting of the three developers and/or a supporting organization could theoretically override the desires of either the program executive office or COMOPTEVFOR. The SMP had obligated the program executive office chairperson and COMOPTEVFOR co-chairperson to support mutually the plan's common goals. For either individual to proceed without the complete concurrence of the other was self-defeating, regardless of developers' positions. So in practice, voting was irrelevant and ultimately eliminated; a simple agreement between chair and co-chair moved the SCP forward.

Lesson 2
Only one SCP existed for all seven models and simulations. The Tomahawk Program's original concept of one SCP per model was good, but considered impractical for SPY-1D(V) because of time and money constraints. So, each SCP meeting addressed all the concerns and problems associated with each model and simulation. As test time drew near, with much left to do, this "do-everything-at-SCP-meeting" approach failed. The SCP could not efficiently handle all the requirements of Simulation Validation Report development for seven models. Simulation Validation Plan writing turned out to be much more challenging and controversial than anticipated. The SCP eventually became so inundated, a permanent session appeared necessary.

The solution was to break up the SCP into smaller teams that each dealt with a subset of Simulation Validation Reports. This allowed the available expertise to focus more completely and exactly than before. One team's membership consisted of two Lockheed Martin experts as well as representatives from the Naval Surface Warfare Center and Center for Naval Analyses. Another team included an AEGIS Technical Representative staffer, a Lockheed Martin engineer, and an OPTEVFOR analyst. Representation on each team also included the program executive office and COMOPTEVFOR. When a team wished to present a viable product, the membership convened the formal SCP.

Lesson 3
The honesty and integrity of all the participants in the verification and validation process was absolutely vital to its credibility. The co-chairing offices hid nothing from external observers, including some rather high-spirited controversies. One developer immediately revealed a model's limitation, newly discovered during verification and validation, that impacted unfavorably on its use. To their credit, the supporting activities focused their attention on problem solving, not just problem noting.

Conclusion

The net result of this rather involved process had several positive elements. All parties learned that a model's legacy is not sacrosanct. We uncovered preexisting, unknown capabilities and limitations that led to a more precise use of the models and simulations and a more accurate interpretation of test data. Ultimately, we achieved a high degree of confidence in the capabilities as well as the limitations of the models and simulations. The program executive office and its developers also gained fresh insight about their models and simulations and how to improve them.

And finally, COMOPTEVFOR authored an operational test plan that realistically and fairly tested the radar at CSEDS. ASN(RDA)'s acquisition strategy worked as intended, and the Navy saved a lot of time and money. Common sense and teamwork made this process viable and successful. DoD will see more of these efforts in future programs as the program office/developer/operational tester combination works smarter to place the best technology available in the hands of the warfighter.

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